

# High Time to Assess the Environmental Impacts of Cannabis Cultivation

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On November 8, 2016, four additional U.S. states (California, Massachusetts, Nevada, and Maine) legalized the use of recreational marijuana and four more relaxed medical marijuana laws. This is effectively creating a new industry in United States, one that looks set to rival all but the largest of current businesses with projected income expected to exceed that of the National Football League by 2020. In Colorado sales revenues have reached \$1 billion, roughly equal to that from grain farming in the state and a third higher than residential construction,<sup>1</sup> an industry with strict environmental monitoring procedures.

The few studies that have investigated specific practices associated with marijuana cultivation have identified potentially significant environmental impacts due to excessive water and energy demands and local contamination of water, air, and soil with waste products such as organic pollutants and agrochemicals<sup>2,3</sup> (see Figure 1). *Cannabis* spp. require high temperatures (25–30 °C for indoor operations), strong light (~600 W m<sup>-2</sup>), highly fertile soil,<sup>2</sup> and large volumes of water (22.7 l d<sup>-1</sup> per plant,<sup>3</sup> around twice that of wine grapes<sup>3</sup>). A study of illegal outdoor grow operations in northern California found that rates of water extraction from streams threatened aquatic ecosystems<sup>3</sup> and that water effluent contained high levels of growth nutrients, as well as pesticides, herbicides and fungicides, further damaging aquatic wildlife.<sup>3</sup>

Controlling the indoor growing environment requires considerable energy inputs, with concomitant increases in

greenhouse gas emissions.<sup>2</sup> It has been estimated that the power density of marijuana cultivation facilities is equal to that of data centers and that illicit grow operations account for 1% of the U.S.'s average energy usage.<sup>2</sup> The carbon footprint of indoor growing facilities, however, is heavily dependent on the power source. For example, illicit growers relying on generators produce more than three times the CO<sub>2</sub> of facilities powered by the grid.<sup>2</sup> There is, therefore, significant potential to reduce both the energy consumption and the carbon footprint through more informed decisions regarding growing conditions, the equipment used and the power source.

Considerably less is known about the potential impacts of this industry on indoor and outdoor air quality. Sampling carried out in conjunction with law enforcement raids on illicit grow operations have measured concentrations of highly reactive organic compounds that were 5 orders of magnitude higher than background.<sup>4</sup> These compounds have clear implications for indoor air quality and thus occupational health, but also on outdoor air quality. In regions where volatile organic compound (VOC) emissions are low relative to those of nitrogen oxides (released from combustion processes), even a small increase in VOC emissions can result in production of secondary pollutants such as ozone and particulate matter. Since these latter compounds are both criteria air pollutants, such a shift in conditions could then lead to nonattainment of the National Air Quality Standards.

Previous studies have been hampered by a lack of reliable data<sup>5</sup> on which to base assessments of the likely consequences of large-scale cultivation and production of marijuana (see Figure 1). The impacts are therefore predicated on conditions and practices prevalent in illicit grow operations. Given that the methods employed in these illegal operations are driven by the need for secrecy, the methods have not been optimized to minimize environmental damage. This speaks to the urgent need for rigorous scientific research and evaluation to aid the new industry and relevant regulatory bodies in assessing the current environmental threats of marijuana cultivation, identifying the opportunities to mitigate such impacts, and developing a framework of stewardship worthy of a modern progressive industry.

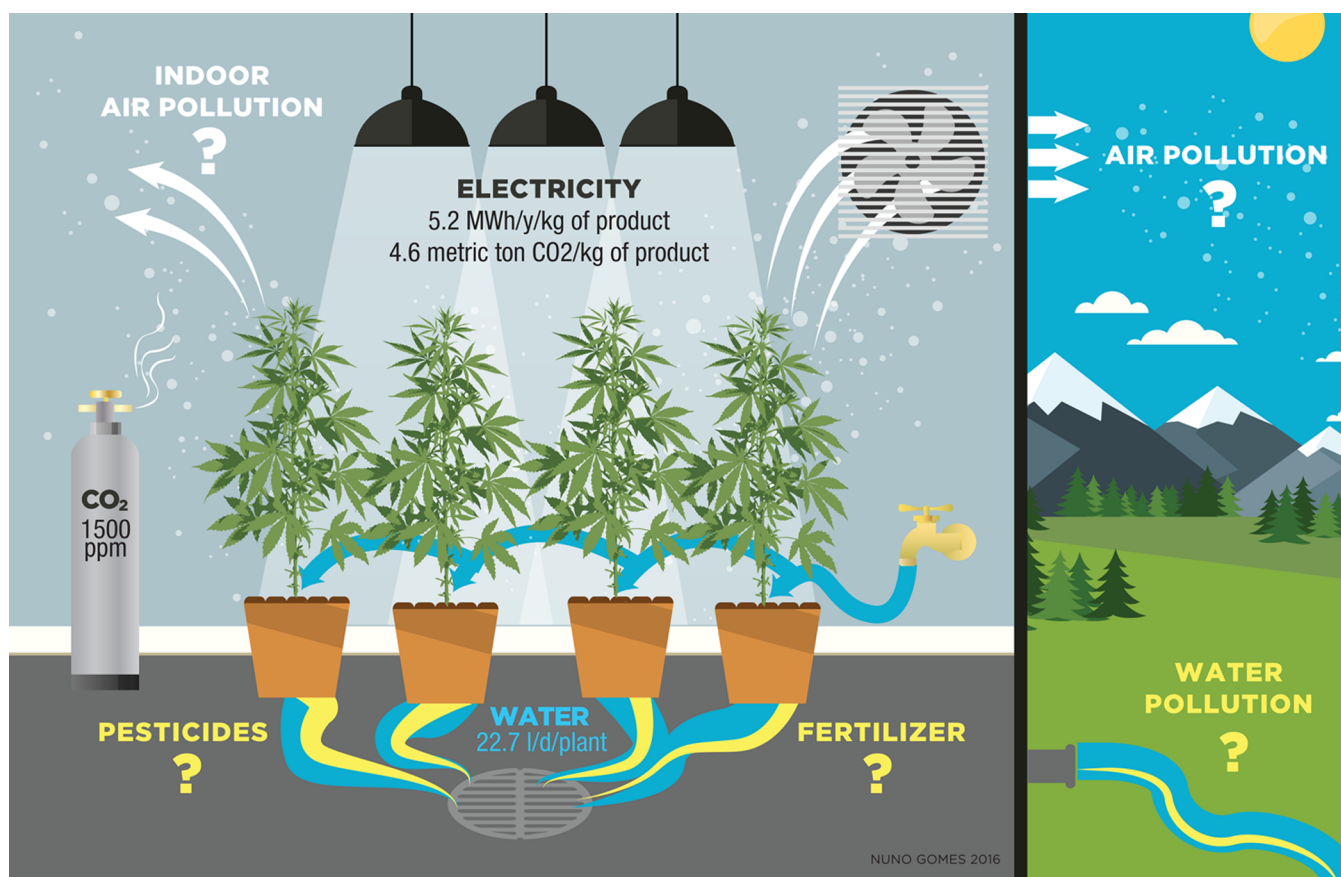
Research, both fundamental and applied, is required in the following areas:

Agronomy and plant physiology:

- determine growth rates and cycles of commonly grown *Cannabis* spp. strains;

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**Figure 1.** Environmental impacts of indoor marijuana cultivation<sup>1–3</sup> (a question mark indicates that the magnitude of the effect has not been previously estimated). Figure credit: Nuno Gomes 2016.

- determine optimal growth conditions for each stage of the growing cycle;
- identify best practices for minimizing water use and irrigation; and
- identify best practices for minimizing fertilizer, fungicide, and pesticide application.

#### Waste treatment and management:

- analyze wastewater streams, evaluate pollutant concentrations and explore the possibility of (a) reducing pollution through good agronomy practice and (b) pretreating effluents before discharge; and
- identify best practices for reducing solvent use for processing harvested plant material, and for treating waste prior to discharge.

#### Outdoor air quality:

- identify and measure emission rates of volatiles from *Cannabis* spp. at different developmental stages and growing conditions;
- identify and measure emission rates of volatiles from soils and plant detritus;
- measure concentrations of trace gases and particles in grow operations and the atmosphere outside such facilities; and
- identify opportunities for reducing emissions.

#### Occupational health

- identify and quantify the risks to workers exposed to conditions encountered within grow operations.

Such research falls firmly within the remit of U.S. Federal funding agencies, including the U.S. Department of Agriculture, Environmental Protection Agency, National Institutes of Health, and Occupational Safety and Health Administration. The ambiguous legal status of marijuana in the U.S., however, has made it historically difficult for these agencies to actively fund research in this field.<sup>5</sup> We call for this situation to be urgently addressed and funding made available to determine the risk posed to the workforce, the public and the natural environment by this burgeoning industry.

This is an industry undergoing a historic transition, presenting an historic opportunity to be identified as a progressive, world-leading example of good practice and environmental stewardship. Such recognition would lend itself to branding via an “eco-label” scheme that could include formulation of exemplar practices and procedures at every stage of production and supply such as those found in the Marine Stewardship Council’s “Certified sustainable seafood.” Advanced certification could encourage on-site energy generation from renewable sources, treatment and reuse of irrigation water, and organic growing practices. Such a scheme would provide an incentive for businesses to engage with local agencies, communities and regulators to conduct full environmental impact assessments of marijuana grow operations to minimize risk. This inclusive solutions-based approach would set the bar in accountability and transparency, allowing consumers to make a genuine choice and establishing a progressive business model fit for the 21st century that could act as a roadmap for others to follow.

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### Notes

The authors declare no competing financial interest.

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